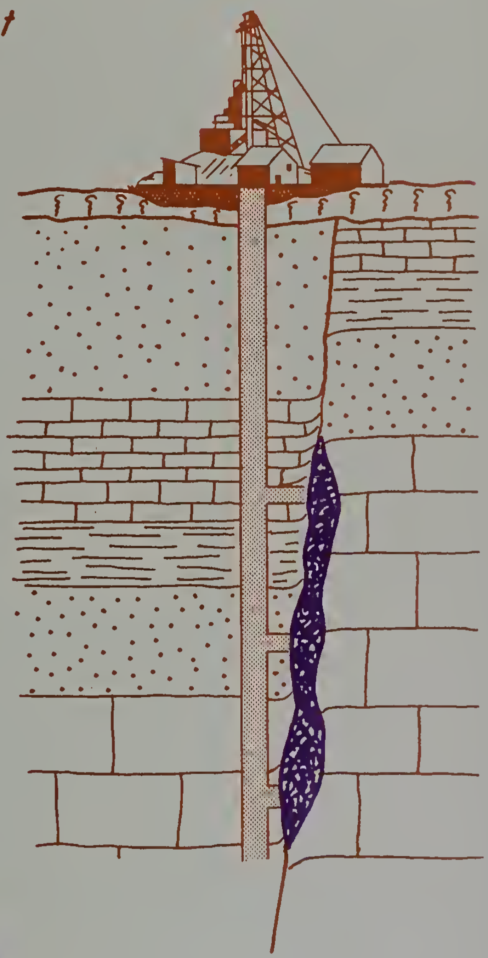
Prepared for the Ninth Annual Forum
on the Geology of Industrial Minerals
Paducah, Kentucky, April 27 — 28, 1973

A GEOLOGIC EXCURSION TO FLUORSPAR MINES IN HARDIN AND POPE COUNTIES, ILLINOIS

Illinois — Kentucky Mining District and Adjacent Upper Mississippi Embayment



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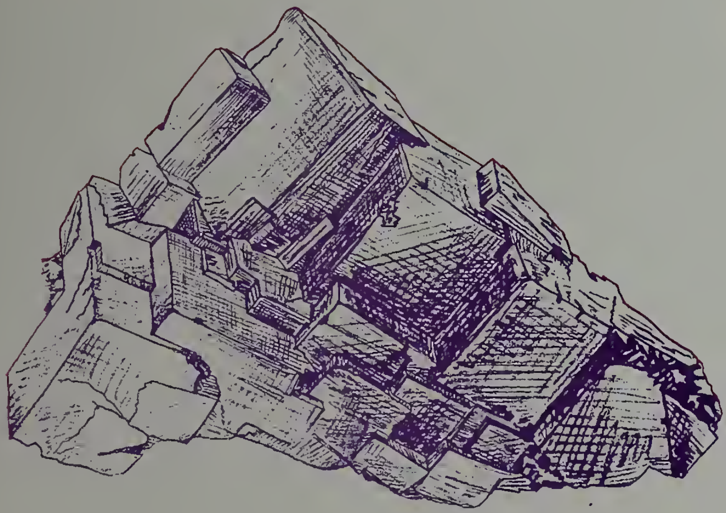

Illinois State Geological Survey Guidebook Series 11

Advertisement for fluorspar, circa 1880. Continued on page 30 and on inside back cover.

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James W. Baxter, James C. Bradbury, and Norman C. Hester
Illinois State Geological Survey

INTRODUCTION

This guidebook was prepared to provide background information on the geology of the Illinois portion of the Illinois-Kentucky fluorspar district and to present detailed information on two Illinois mines that will be visited on a one-day excursion from Paducah, Kentucky. Mining and milling of fluorspar date back to an early period in the history of the area. Operations, begun in 1839, were first directed to the extraction of galena that, mixed with sphalerite, occurs with fluorspar in some deposits. The importance of these deposits is well illustrated by the variety of uses of fluorspar and its chemical derivatives in modern technology (Bradbury, Finger, and Major, 1968).

The Illinois portion of the Illinois-Kentucky mining district lies within a structurally complex part of the Shawnee Hills section of the Interior Low Plateau Physiographic Province (fig. 1) and is underlain largely by rocks of Mississippian age. The route from Paducah to the mines crosses sediments of the Mississippi Embayment of the Coastal Plain Province. Although this area is not considered a part of the mining district, its geologic history and stratigraphy are important in the understanding of the structural development of the district. Although the time required for the underground trips does not leave sufficient time for stops enroute to the mines, the stratigraphy of the Embayment sediments is outlined herein and sites of particular interest will be pointed out by guides.

The day has been planned to include underground trips that provide the opportunity to study typical ore bodies of both the fissure-filling, or vein, type and the flat-lying replacement, or bedded, type. At the Gaskins Mine, an example of vein deposits, the host will be The Minerva Company. The Davis-Oxford Mine, in the Cave in Rock bedding replacement deposits, will be shown by Ozark-Mahoning Company, Mining Division. The field trip committee wishes to express its appreciation to these companies and to thank D. B. Saxby, Chief Geologist, The Minerva Company, and B. L. Perry, Chief Geologist, Ozark-Mahoning Company, Mining Division, for their contributions to this guidebook.

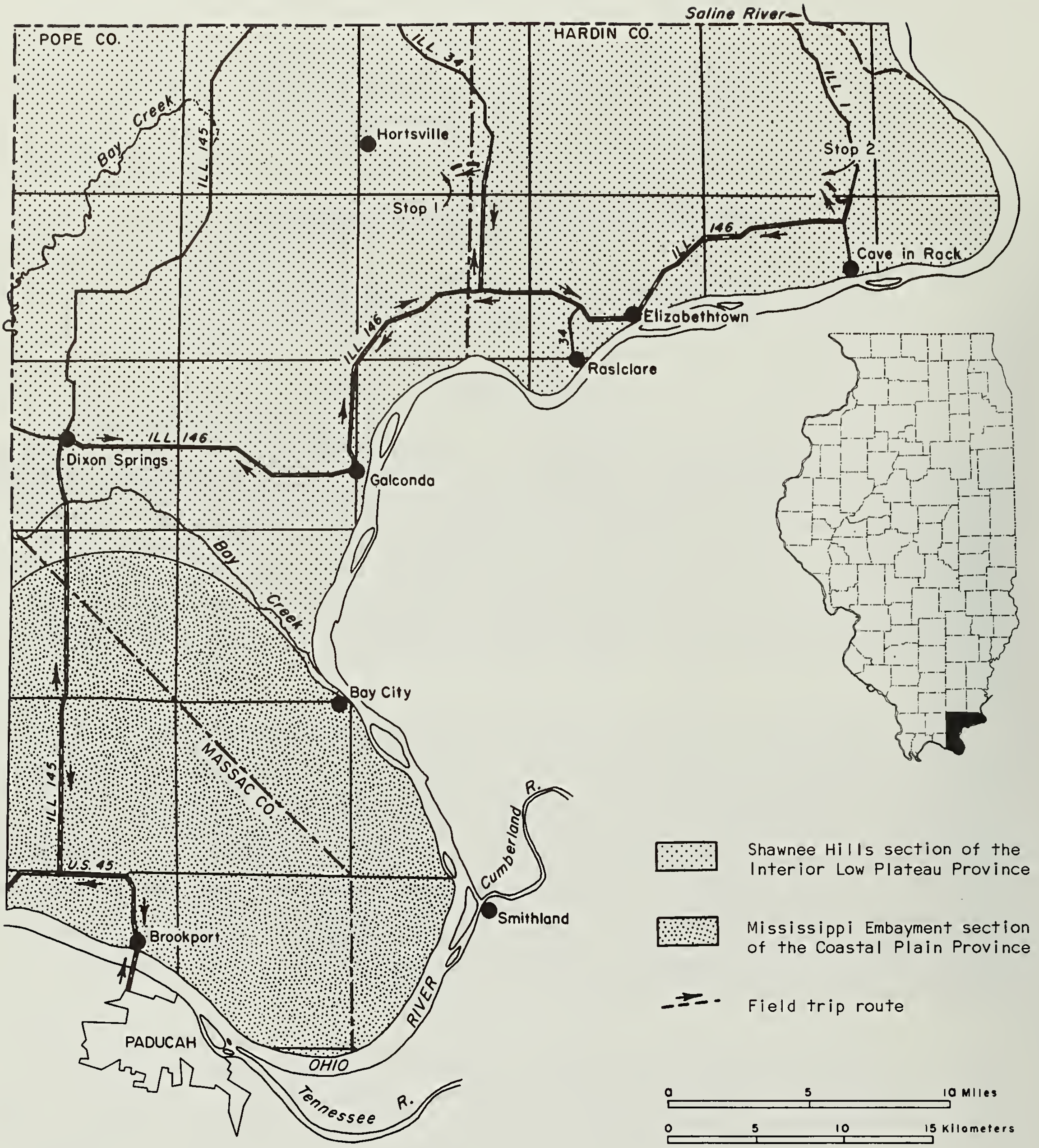

Fig. 1 - Physiography of the field trip area.

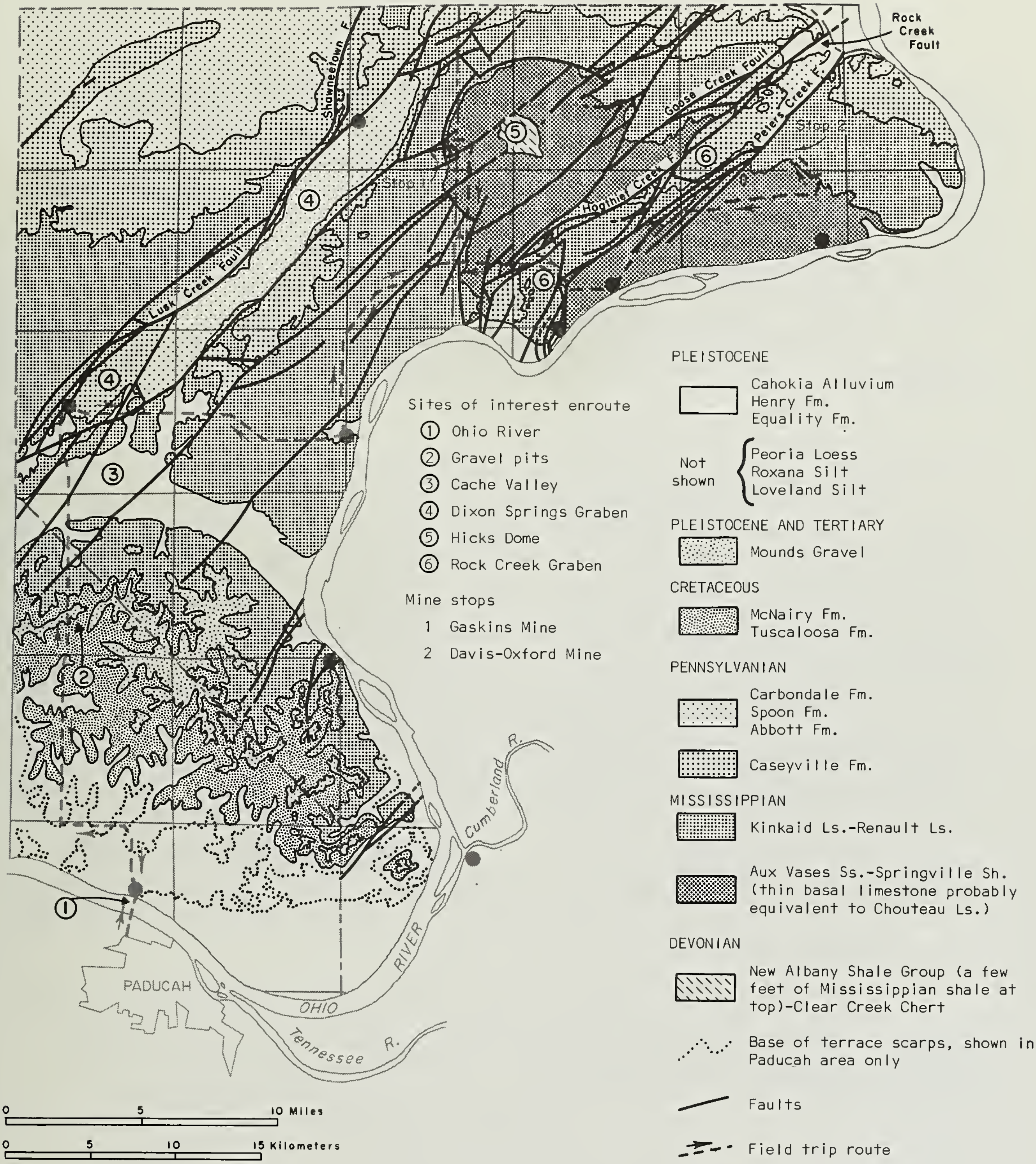

Fig. 2 - Geology of the Illinois portion of the Illinois-Kentucky fluorspar district and field trip route from Paducah, Kentucky.

Mississippi Embayment Sediments

Late Cretaceous and early Tertiary strata of the Mississippi Embayment extend into extreme southern Illinois and western Kentucky and come within a few miles of the southern edge of the fluorspar district (fig. 2). At the upper end of the Embayment these strata consist of unconsolidated marine and nonmarine clays and sands and nonmarine gravels. A zone of weathering residuum, developed on the Paleozoic rocks and called the Little Bear Soil, underlies the Cretaceous beds in places. Figure 3 shows the stratigraphic units of the Embayment sediments in southern Illinois as recognized by the Illinois State Geological Survey. Figure 4 shows the stratigraphic units of Late Cretaceous to Holocene age as recognized by Olive (1972). This column for western Kentucky shows Middle and Upper Eocene formations that are not present in Illinois and illustrates a different interpretation of the boundary between the Cretaceous and the Tertiary.

Cretaceous strata

Tuscaloosa Formation. The basal Cretaceous unit, which has been correlated with the Tuscaloosa Formation of Alabama and Tennessee, consists of lenses of chert gravel and clayey sand. Although lithologically similar to the type Tuscaloosa and occupying a comparable (basal) position in the Embayment sediments, there is some question whether the Illinois and Kentucky Tuscaloosa might not be, in fact, a basal conglomerate of the overlying McNairy Formation and, therefore, somewhat younger than the Alabama and Tennessee Tuscaloosa.

McNairy Formation. The McNairy Formation is a dominantly regressive, arenaceous, clastic wedge, the result of a prograding deltaic system, that directly overlies Paleozoic rocks, the Little Bear Soil, or the Tuscaloosa Formation. According to Pryor and Ross (1962, p. 19), the McNairy "is composed of nonmarine, fine, cross-stratified, micaceous sands, with numerous thin beds of lignitic silt and clay." However, the recognition of the trace fossil *Ophiomorpha nodosa* (a burrow of the decapod crustacean *Callianassa*, which occupies near-shore marine and estuarine environments) in the upper part of the McNairy near Olmsted, Illinois, demonstrates that the McNairy is, in part, marine in origin. This trace fossil was also observed (Olive, 1972) in the McNairy Formation near Paducah, Kentucky.

As reported by Pryor and Ross (1962, p. 20), the presence of calcareous sands encountered in the Vick Oil Company No. 1 Smith well in the southern part of the Thebes Quadrangle also suggests that "the sands were deposited on a marine delta platform." Clays and silts become more predominant in the upper part of the McNairy Formation, and a well-defined lignitic silt and clay unit has been named the Levings Member by Pryor and Ross (1962). In the Paducah area, the McNairy is approximately 200 feet thick. Only the lower part of the McNairy underlies the surface of the Illinois portion of the Paducah Quadrangle that is crossed via Illinois 145 on the trip to the mines. Wells at Metropolis, Illinois, about 5 miles west of Brookport, however, reportedly encountered the Levings Member (Ross, 1964, p. 14).

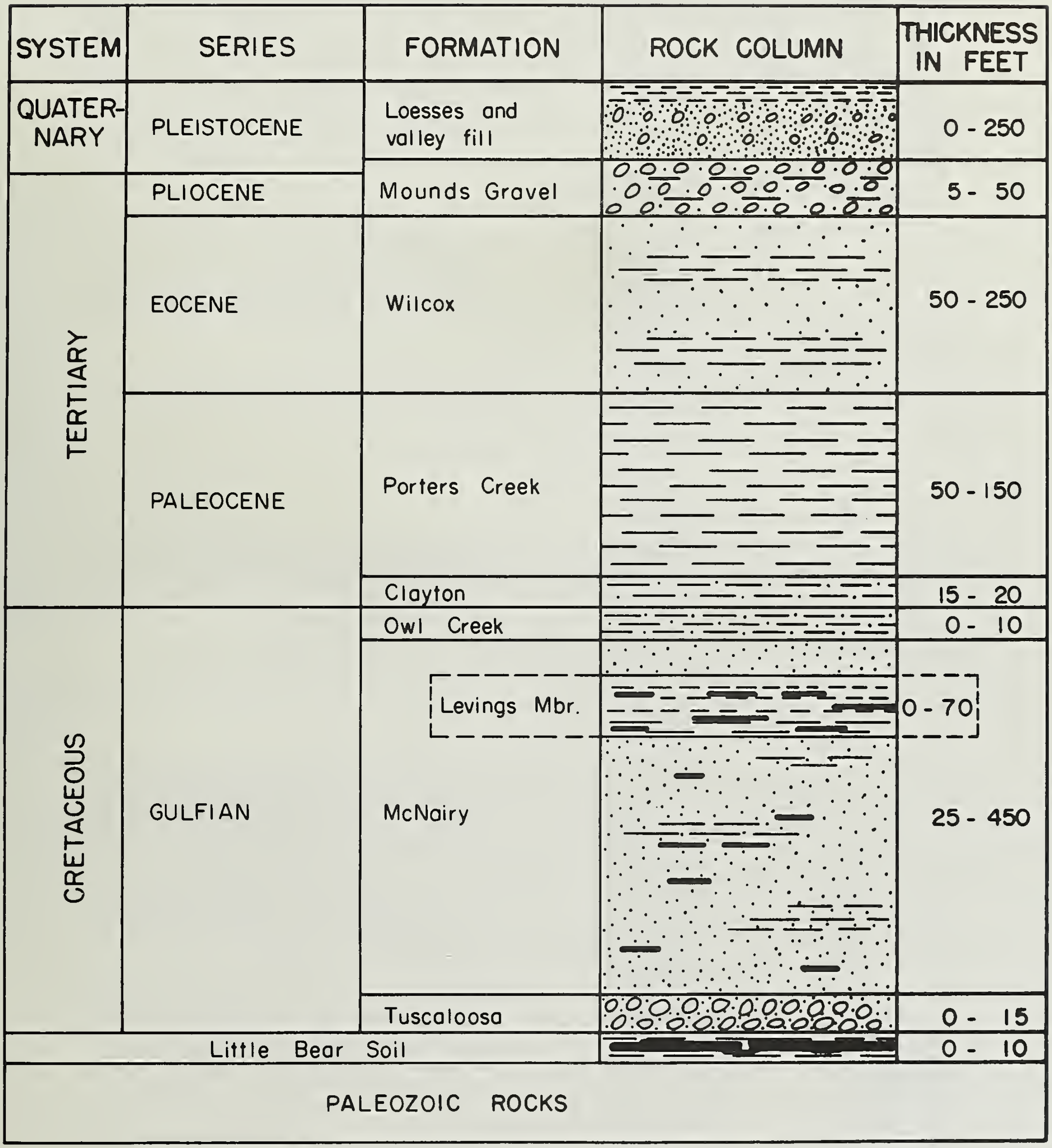

Fig. 3 - Detailed columnar section of Cretaceous-Tertiary strata in southern Illinois, modified from Pryor and Ross (1962, fig. 5).

SYSTEM	SERIES	GROUP AND FORMATION	LITHOLOGY	THICKNESS (feet)	CHARACTER*
QUATERNARY	Holocene and Pleistocene	Alluvium and lacustrine deposits		0-185	Brown to gray silt, sand, and gravel; rarely calcareous. Thickest beneath flood plains of Mississippi, Ohio, and Tennessee Rivers.
QUATERNARY	Pleistocene	Loess		0-80	Brown to gray silt, intermixed with minor amounts of clay and fine sand; nonstratified blanket-like deposit; locally calcareous and fossiliferous. Thickest near Mississippi River; thins eastward.
QUATERNARY	Pleistocene	Continental deposits		0-100	Brown to reddish-brown gravel; pebbles dominantly chert and subordinately quartz; scattered lenses of clay and sand; contains fairly continuous middle member composed of sand and clay in south-central part of region. Thins northward and westward.
TERTIARY(?) AND QUATERNARY	Pliocene(?) and Pleistocene				
TERTIARY	Eocene	Jackson Formation		400±	Brown to gray silt and clay with thin beds and lenses of light-colored quartz sand; crossbedded in part; very sparse clay-ball sand; locally abundant carbonized plant remains; probably intergrades with Claiborne. May include beds of Oligocene age in upper 100 feet of sequence. Thickens toward axis of Mississippi embayment.
TERTIARY	Eocene	Claiborne Formation		500±	Light-colored quartz sand with thin lenses of dominantly gray silt and clay; commonly crossbedded; numerous clay-ball sand beds; carbonized plant remains common in clay; locally contains thin lignite beds. Overlies Wilcox Formation unconformably in most of area; overlaps Wilcox in east-central part of area and lies unconformably on Porters Creek Clay.
TERTIARY	Eocene	Wilcox Formation		0-350+	Light-colored clayey quartz sand and sandy clay commonly referred to as "sawdust sand" which is characterized by white kaolinite clay grains and minute striate rods; thin beds and lenses of clay and crossbedded sand, clay-ball sand lenses; basal coarse sand common. Unconformably overlies Porters Creek Clay.
TERTIARY	Paleocene	Midway Group: Porters Creek Clay		65-230	Light- to dark-gray montmorillonitic clay, locally glauconitic; beds of gray to brown micaceous and generally glauconitic sand common in lower and upper parts; intersected at many places by vertical to near-vertical clastic dikes. Overlies Clayton and McNairy Formations, conformably in most places.
CRETACEOUS AND TERTIARY	Upper Cretaceous and Paleocene	McNairy and Clayton Formations		125-275	Gray to brown interlensing sand and clay, characterized by thin laminae, blebs, and minute lenses of white, clean, very fine micaceous quartz sand; local lignite bed. Lower part dominantly light-gray to brown crossbedded quartz sand; carbonized plant remains and iron sulfide nodules common; sparse scattered lenses of chert-pebble and quartz-sand-matrix gravel in lower 50 feet. Unconformably overlies Tuscaloosa Formation and Paleozoic rocks.
CRETACEOUS	Upper Cretaceous	Tuscaloosa Fm.		0-165	Pale-gray to pale-orange chert-pebble gravel in a chert-sand, silt, and clay matrix; contains irregularly spaced thin lenses of chert sand, silt, and clay. Formation occurs as scattered lenses in area bordering Kentucky Lake. Unconformably overlies Paleozoic limestone, chert, and shale.
			O — Glauconite		* Modification of Olive and Finch (1969, p. 5-6)

Fig. 4 - Generalized section of stratigraphic units of Late Cretaceous to Holocene age in the Jackson Purchase region. Illustrates present U.S.G.S. classification of sediments of the Mississippi Embayment. From Olive (1972, table 1).

Cretaceous-Tertiary Boundary. Lying above the McNairy Formation in a zone that brackets the boundary between the Cretaceous and the Tertiary is approximately 20 to 30 feet of glauconitic, clayey, fossiliferous, burrowed marine sands. The stratigraphic nomenclature for this particular interval is at present controversial. Pryor and Ross (1962) have defined two units in this zone on the basis of unconformities and the glauconitic and fossiliferous character of the sediments. These are the Upper Cretaceous Owl Creek Formation and the Tertiary Clayton Formation. The United States Geological Survey (see e.g., Finch, 1967; Olive and Finch, 1969; Olive, 1972) does not recognize the name "Owl Creek" nor an unconformity at the base of the Clayton. As an alternative, it groups the McNairy and Clayton and makes no distinct break between the Cretaceous and the Tertiary (fig. 3).

Owl Creek Formation. The Owl Creek Formation, at the top of the Cretaceous succession in the southern Illinois area, is represented only by erosional remnants of glauconitic, sparsely fossiliferous silty clays and silts (Pryor and Ross, 1962, p. 21). It unconformably overlies the McNairy Formation. It is found in the Cairo area at the southwestern tip of Illinois and in western Kentucky, but it is not known to be present in the eastern portion of the Embayment sediments of Illinois.

Tertiary strata

Tertiary strata are limited to the Cairo area of the Illinois portion of the Embayment but are present over most of the western Kentucky portion.

Clayton Formation. The Paleocene Clayton Formation unconformably overlies the Owl Creek and McNairy Formations. It "consists of glauconitic, sparsely fossiliferous and micaceous, green to buff clays" (Pryor and Ross, 1962, p. 24). It is generally 15 to 20 feet thick.

Porters Creek Formation. The Paleocene Porters Creek Formation conformably overlies the Clayton and is well exposed in extreme southwestern Illinois in the small tributary streams along the Ohio River bluff south of the old location of U.S. Dam 53. It consists of massive, blocky, essentially unlaminated, sparsely fossiliferous, black to grayish tan clays. Its thickness ranges from 50 to 150 feet, increasing southward. Because this sediment has a very high percentage of the expandable clay mineral montmorillonite, it is marketed for its absorptive properties as "Kitty Litter" and sweeping compound.

Wilcox Formation. The Eocene is represented in Illinois only by the Lower Eocene Wilcox Formation. However, the Middle Eocene Claiborne and Upper Eocene Jackson Formations (fig. 4) are present over a considerable portion of the Embayment in western Kentucky.

The Wilcox consists of micaceous, lignitic clays and silts and interbedded cross-stratified sands. It unconformably overlies the Porters Creek Formation and ranges from 50 to 150 feet thick.

Claiborne Formation. The Claiborne Formation has not been recognized in Illinois; however, in western Kentucky this unit attains thicknesses ranging up to 600 feet. It consists of predominantly nonmarine sands with layers and lenses of silt and clay that contain some thin beds of lignite. This unit is unconformable with the underlying Wilcox, and in the east central part of the Jackson Purchase, it lies unconformably on the Porters Creek Formation (Olive and Finch, 1969). Clay deposits occurring as widely spaced lenses in the Claiborne consist predominantly of kaolin and serve as a major domestic source of ball clay (Olive and Finch, 1969).

Jackson Formation. The Jackson Formation is not present in Illinois but reaches thicknesses exceeding 400 feet in western Kentucky. It consists principally of silt and clay and has thin beds of quartz sand. According to Olive and Finch (1969), it probably intergrades with the Claiborne. Because the clay deposits in the Jackson contain montmorillonite in excess of 10 percent, the unit is not a source of ceramic clay.

Tertiary-Quaternary strata

The Mounds Gravel Formation (Willman and Frye, 1970) was formerly called "Lafayette" Gravel in southern Illinois (Pryor and Ross, 1962, p. 28) and is referred to Pliocene (?)-Pleistocene continental deposits in western Kentucky (Finch, 1967). It consists of brown chert gravel and associated red sands and is commonly found capping hills and ridges. Its thickness may be as great as 50 feet. The Mounds truncates Paleozoic, Mesozoic, and Tertiary formations in southern Illinois and western Kentucky; farther south it truncates Pliocene sediments and is therefore Pliocene or younger. As the Mounds Gravel lacks the mineralogy commonly associated with glacial sediments, it has previously been dated as Pliocene; however, Willman and Frye (1970, p. 48) prefer to assign it a Pliocene-Pleistocene age.

The Mounds is relatively common on the hills and ridges along Illinois 145 in the area traversed on the field trip. This gravel is an important local source of road metal.

Quaternary strata

The field trip area lies south of the extent of Pleistocene continental glaciation. Deposits of Pleistocene age in the area consist of loess, lacustrine silt and sand, outwash sand and gravel, and alluvial silt and sand.

Peoria Loess. Loess of aeolian origin, generally less than 15 feet thick, caps the hills along the field trip route. The loess is principally the Peoria Loess of Woodfordian age, but in places the lower part includes a few feet of dark brown Roxana Silt of Altonian (early Wisconsinan) age. Locally, there is a thin deposit of reddish brown, very clayey silt correlated with the Loveland Silt of Illinoian age.

Equality Formation. Slack-water deposits occur in fill terraces along the Ohio River near Paducah and along the Cache Valley and in remnants of terraces along the Ohio River above the Cache. These sediments, of lacustrine origin, are largely of Woodfordian age and are correlated with the Equality Formation (Willman and Frye, 1970, p. 72).

Henry Formation. The low terrace at Brookport, Illinois, is cut in valley fill that may be best correlated with the Henry Formation (Willman and Frye, 1970).

Cahokia Alluvium. Deposits of coarse gravels and sand overlie bedrock along the course of the Ohio River Valley (Ross, 1964). These deposits were probably derived from the Mounds Gravel and reach a thickness of 100 feet in the Black Bottom. The most recently deposited alluvial sediments of the Ohio River floodplain are silt and sand that are 30 to 40 feet thick. These overlie the coarse alluvium, and both are correlated with the Cahokia Alluvium (Willman and Frye, 1970, p. 75), which is late Wisconsinan and Holocene in age.

Enroute, Site 1. Ohio River Floodplain

North of Paducah the route crosses the Ohio River, and on the right lies the widening floodplain known as the Black Bottom. The Tennessee River, entrenched along the Cretaceous-Tertiary contact, enters the Ohio River at Paducah, and the Cumberland River, similarly entrenched parallel to the Cretaceous-Paleozoic boundary, enters the Ohio River at Smithland, Kentucky.

Prior to late Pleistocene time, the Ohio River occupied the broad alluvial Cache Valley (Enroute, Site 3) about 15 miles to the north and the Cumberland River flowed north from Smithland to the Cache Valley near Bay City. Approximately 10,000-20,000 years ago the Ohio River was diverted from the Cache Valley, and in establishing its present position, it flowed up the Cumberland, across a narrow divide near Smithland, and down the lower reaches of the Tennessee. The shift in the Ohio River may have been related to an unusually high flood stage such as the Kankakee Flood.

Enroute, Site 2. Pits in the Mounds Gravel

Pits in this area are in the Mounds Gravel, which consists of chert gravel and associated red sand. These upland gravel deposits, previously termed "Lafayette" in southern Illinois, are composed dominantly of dark, olive-brown chert pebbles that may reach 2½ to 3 inches in longest dimension but are usually smaller, 3/4 to 1 inch. Most are considerably rounded and some are well rounded.

The section here is as follows:

	Feet
Quaternary System	
Pleistocene Series	
Peoria Loess	
Loess	8-10
Quaternary-Tertiary Systems	
Pleistocene-Pliocene Series	
Mounds Gravel	
Gravel, rounded chert pebbles to 2 inches in diameter, containing much limonitic clay; cemented in part by limonite. Gravel generally cross-bedded.	20.0
Chert conglomerate heavily cemented with limonite	0.5
Red sand (possibly Cretaceous)	3.0

Enroute, Site 3. Cache Valley

The valley of the pre-glacial Ohio River, entrenched across the southern tier of counties in Illinois, follows a course along the southern margin of the Shawnee Hills and hence closely parallels the Cretaceous-Paleozoic contact. At this point the valley is about 3 miles wide and is drained by a small east-flowing stream, Bay Creek, that enters through a break in the north wall about 2½ miles to the west. Beyond the western extent of Bay Creek, the valley is occupied by a series of west-flowing creeks and drainage ditches, and still farther west by the Cache River, into which these waterways flow.

The north valley walls are here eroded in faulted Paleozoic rocks and are steeper and more irregular than those on the south, which are cut partially in weaker Embayment sediments that are preserved on the uplands.

The Cache Valley is entrenched 250 to 400 feet below the uplands, and the valley fill consists of up to 180 feet of sands, clays, and gravel. Much of the bottomland of the Cache Valley is formed by a terrace having the elevation of the low terrace of the Ohio River at Brookport (Ross, 1964, p. 18).

Illinois-Kentucky Fluorspar District

The Illinois-Kentucky fluorspar district is in a complexly faulted area that is situated between the Illinois Basin to the north and northeast and the Mississippi Embayment to the southwest (fig. 5). The Ozark Uplift lies to the west, and the Nashville Dome and Cincinnati Arch lie to the southeast.

Sedimentary rocks

Mississippian limestones, shales, and sandstones underlie most of the fluorspar district. Older strata, of Devonian age, are exposed on

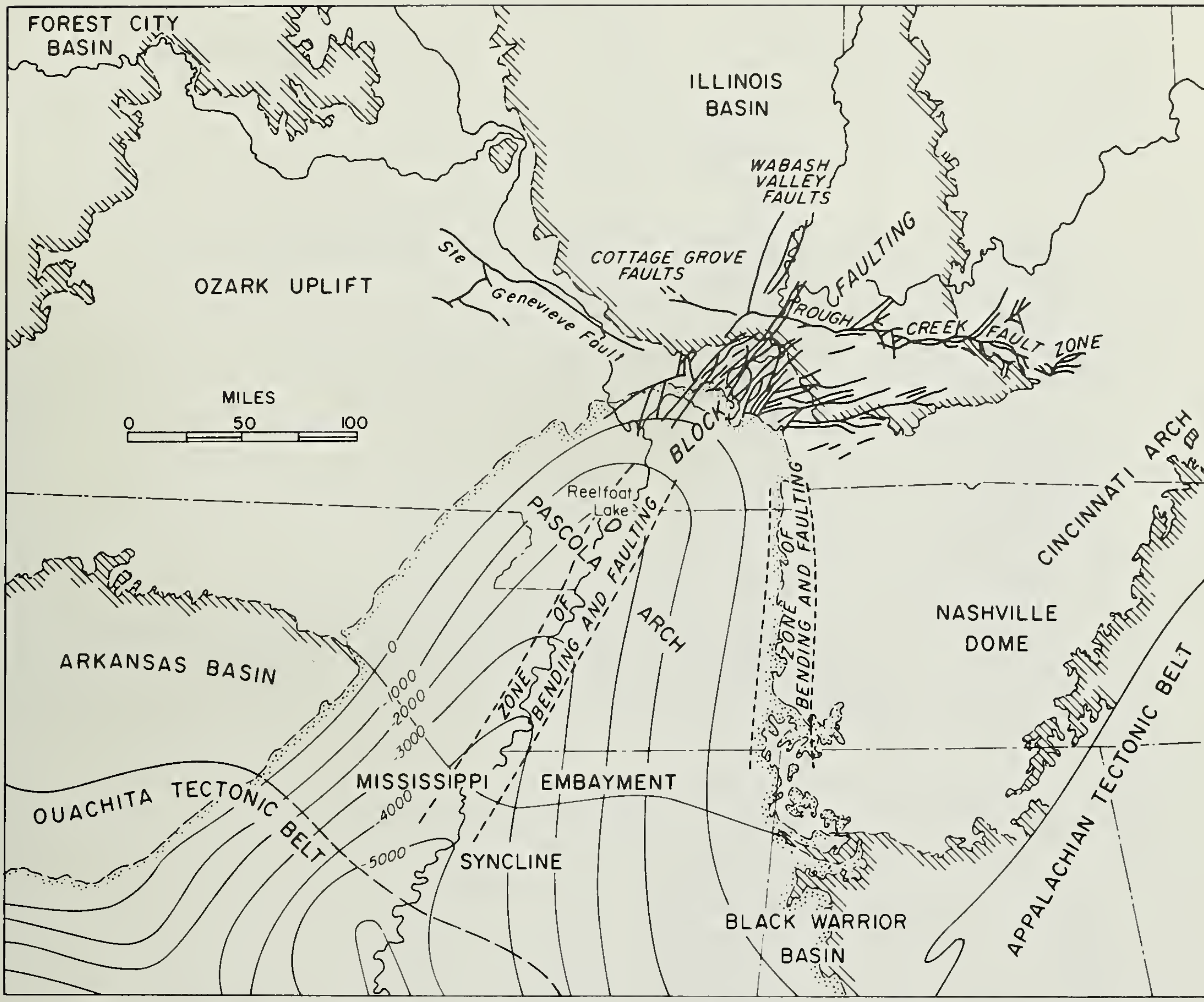

Fig. 5 - Regional structural setting of the Illinois-Kentucky mining district. From Ross (1963, fig. 2, as adapted from U.S.G.S. and AAPG, 1962, "Tectonic Map of the United States," and with zones of bending and faulting within the Embayment Syncline suggested by Stearns and Marcher, 1962, p. 1391.) Diagonal shading outlines areas of Pennsylvanian strata; dotted shading outlines areas of Cretaceous-Tertiary strata. Contours are drawn on top of Cretaceous.

Hicks Dome in the northwestern part of the district, where Lower and Middle Devonian cherty limestones occur at the center of the dome and are surrounded by a ring of outward-dipping New Albany Shale of Devonian-Mississippian age. Pennsylvanian strata of the Illinois Basin flank the district on the north and east and are preserved in grabens within the district. Figure 6 summarizes the characteristics of the bedrock units.

Late Cretaceous and early Tertiary strata of the Mississippi Embayment extend into extreme southern Illinois and western Kentucky and come within a few miles of the southern edge of the fluorspar district (fig. 2).

Igneous rocks

Numerous dikes of mica-peridotite and lamprophyre are found throughout the district, and intrusive breccias have been discovered at several loca-

SYSTEM	SERIES	FORMATION	MEMBER	LITHOLOGY	THICKNESS (FT.)	LITHOLOGIC DESCRIPTION
PENNSYLVANIAN					600-900	Sandstone, shale, thin coals
MISSISSIPPIAN	CHESTERIAN	KINKAID			0 - 80	Gray, cherty limestone; shale
		DEGONIA			0 - 30	Shale and thin-bedded sandstone
		CLORE			100-120	Shale; limestone; thin-bedded sandstone
		PALESTINE			50 - 60	Sandstone; silty shale
		MENARD			100-130	Fine-grained limestone; shale
		WALTERSBURG			15 - 50	Shale; shaly sandstone
		VIENNA			10 - 20	Limestone; shaly limestone
		TAR SPRINGS			90 - 110	Sandstone; shale; thin coal
		GLEN DEAN			40 - 70	Fossiliferous, partly oolitic limestone; shale
		HARDINSBURG			90 - 115	Sandstone; shale
		HANEY			105-140	Fossiliferous limestone
		FRAILEYS				Shale; thin limestone
		BEECH CREEK				Silty limestone
		CYPRESS			80-110	Sandstone; shale
		RIDENHOWER			25 - 65	Shale; shaly sandstone
		BETHEL			80 -100	Sandstone
		DOWNEYS BLUFF			25 - 40	Crinoidal, locally oolitic limestone
		YANKEETOWN			30 - 45	Shale; siltstone (Yankeetown); limestone; shale (Shetlerville)
	VALMEYERAN	RENAULT	Shetlerville			
			Levias		15 - 35	Light-colored oolitic limestone (Levias)
		AUX VASES	Rosiclare		15 - 35	Calcareous sandstone, shale at base
		STE. GENEVIEVE	Spar Mtn.		120-160	Light-colored, largely oolitic limestone; sandstone lenses
		ST. LOUIS			350-400	Fine-grained, cherty limestone
		SALEM			500±	Dark-colored, fine-grained limestone; foraminiferal calcarenite
		ULLIN			125-360	Crinoidal, bryozoan limestone; dark-gray, fine-grained limestone
		FORT PAYNE			225-640	Siltstone; silty, cherty limestone
DEVONIAN-MISSISSIPPIAN		SPRINGVILLE				Gray and greenish gray shale
		NEW ALBANY GROUP			395±	Gray to black shale
DEVONIAN		LINGLE				
		GRAND TOWER			250±	Limestone and chert
		CLEAR CREEK				

Fig. 6 - Stratigraphic column of exposed Paleozoic formations, Illinois-Kentucky fluorspar district. Adapted from Grogan and Bradbury, 1968. Published with permission of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc.

tions in the Illinois portion of the district (Clegg and Bradbury, 1956; Bradbury, 1962). Igneous rock of another type, possessing many of the mineralogic and textural characteristics of a tinguaite (hypabyssal variety of nepheline syenite), has been found in the northwestern part of the district associated with an intrusive breccia; however, it is uncertain whether the crystalline rock was intruded as a magma or was entrained as a block in the breccia (Grogan and Bradbury, 1968).

The mica-peridotites are dark gray to dark greenish gray, fine- to medium-grained, porphyritic rocks characterized by olivine (mostly serpentinized), phlogopite, and pyroxene. Alteration of the olivine and pyroxene to serpentine and of mica to a green chlorite ranges from slight to intense. Replacement by carbonate ranges from slight to moderate. Apatite is a common accessory.

The lamprophyres are medium to dark gray or medium to dark greenish gray, very fine grained, and porphyritic to non-porphyritic. Replacement by carbonate has been extensive, and in some dikes only the mineral apatite remains to attest to the igneous origin of the rock body. In others, phenocrysts of phlogopite, augite, and serpentine can be observed. The absence of olivine, or of serpentine pseudomorphic after olivine, differentiates lamprophyre from mica-peridotite. The presence of analcite in one of the lamprophyres (Bradbury, 1962) suggests that at least some of the lamprophyres differ in other aspects from the mica-peridotites.

The intrusive breccias are fragmental rocks of dike-like or presumed plug shapes. Many are composed solely of sedimentary rock fragments in a matrix of ground-up sedimentary rock; some contain scattered igneous rock fragments in addition to the predominantly sedimentary ones in a matrix of ground-up sedimentary and igneous rock; and one (Grants Intrusive) contains, in addition to sedimentary rock fragments, a large amount of material of igneous derivation, including crystals of hornblende and biotite as much as 0.5 inch long and fragments of an aegerine-bearing syenite up to 1.5 inches long. The matrix in the Grants Intrusive is carbonate, exhibiting flow lines in places, thereby suggesting that the intrusive may not be entirely a fragmental rock. The carbonate may be primary, as in the carbonatitic breccias of the Monteregian Hills, Quebec (Gold, 1972), or secondary, as generally accepted for the carbonates in the peridotite and lamprophyre dikes of the Illinois-Kentucky area. If secondary, replacement has been so extensive that it cannot be determined whether the original matrix was crystalline or fragmental. At any rate, the mica-peridotites, lamprophyres, and intrusive breccias are indicative of an alkaline igneous province, and it would not be at all unexpected to find a carbonatitic body in such a setting.

Structural setting and development

The fluorspar district is located south and southeast of the Shawneetown Fault Zone, named for Shawneetown, Illinois, where the Rough Creek Fault Zone of Kentucky (fig. 4) enters Illinois. The Shawneetown Fault Zone extends west of Shawneetown to a point in southwestern Saline County where it swings sharply to the southwest and intersects the Dixon Springs Graben near Hartville in Pope County, Illinois (fig. 2). Structurally the district lies within the Illinois Basin. Although for some purposes the southern end of the Illinois Basin is defined as the southern limit of Pennsylvanian strata, as shown in figure 5, the southern limit of northward-dipping Paleozoic strata is defined by the Pascola Arch and the Nashville Dome. The Mississippi Embayment Syncline is, therefore, superimposed on the southern end of the Illinois Basin and thus contributes to the structural complexity of the region.

The structural history of the region in which the fluorspar district is located indicates that the region has been relatively unstable for some time. During the Pennsylvanian (and probably the Permian), the area now occupied by the mineralized district was receiving sediments as a part of a subsiding basin of deposition extending an unknown distance to the south (Potter and Glass, 1958). Probably coincident with the Appalachian Revolution, tectonism took place in the region during or at the end of the Permian and the Pascola Arch (fig. 5) rose and separated the Illinois Basin from the Black Warrior Basin to the south (Atherton, 1971; Stearns and Marcher, 1962).

Igneous activity also occurred during the Permian (Zartman et al., 1967) and presumably pushed up the low, northwest-trending arch now occupied by the fluorspar district, injecting peridotite and lamprophyre dikes into northwest-trending fractures. Ultramafic intrusions, however, were not limited to the mineralized district known at present. Many dikes have been encountered in coal mines several miles north and northwest of known fluorite mineralization (Clegg and Bradbury, 1956), and Omaha Dome, an oil-producing structure 10 miles north of the Shawneetown Fault Zone, is thought to have been uplifted by ultramafic intrusions (English and Grogan, 1948). An explosive phase of igneous activity, resulting in the creation of Hicks Dome (fig. 2) as well as isolated intrusions of breccia throughout the Illinois portion of the fluorspar district, apparently followed dike intrusion, at least in part. Fragments of ultramafic rock in intrusive breccia at two localities indicate that, here at least, dike intrusion preceded brecciation.

Major faulting also is presumed to have taken place at the time of the Appalachian Revolution. High-angle reverse movement along the east-west trending portion of the Shawneetown Fault Zone (fig. 5) resulted in local displacements of 3500 or more feet (Butts, 1925, p. 59) and is generally correlated with the compressional activity of the Appalachian event. The northeast-trending normal faults that are prominent in the fluorspar district and extend to the southwest may have had their inception at this time as compressional shear faults; Saxby (this guidebook, p. 21) mentions the importance of horizontal fault movement and Weller, Grogan, and Tippie (1952) cite evidence of high-angle thrusting along one or more of the larger northeast-trending faults. The block faulting, however, is obviously tensional in nature and can be assumed to have occurred after relaxation of the compressive forces. Precisely when this gravity faulting took place is uncertain, but most, if not all, of the displacement along the northeast-trending shear faults appears to have been accomplished prior to the beginning of Cretaceous deposition in the northern part of the Mississippi Embayment.

The Mississippi Embayment Syncline began receiving sediments in Late Cretaceous time (Tuscaloosa Formation) and experienced its greatest development during the Eocene (Stearns and Marcher, 1962, p. 1390). During this period of downwarping, the crest of the Pascola Arch was depressed more than 2000 feet, from a topographic high at the beginning of the Late Cretaceous to an elevation much below the present southern rim of the Illinois Basin. Structurally, however, the buried Pascola Arch remains a controlling factor and the Paleozoic strata still dip northeastward from its northern flank into the Illinois Basin.

Bending of the strata during the sinking of the Embayment was not uniform, and most of the bending occurred along the synclinal axis, the position of which appears to coincide with the northeast-trending New Madrid Fault Zone. Cretaceous and Tertiary strata that appear to have been displaced to some extent have been reported at the north end of the Embayment (Ross, 1964), but the underlying Paleozoic rocks had evidently been displaced to a much greater extent before the Embayment sediments were deposited (Ross, 1963). Although there is a coincidence of earthquake epicenters with the Mississippi Embayment zone of bending and faulting (McGinnis, 1963), evidence that surface faults are still active has not been established.

In summary, the structural configuration of the district seems to have begun with warping and igneous activity coincident with the Appalachian Revolution in Permian time. Major faulting appears also to have begun about this time and may have continued well into the Mesozoic. By Late Cretaceous time, when warping again became predominant, major fault movements and the structural details of the mineralized district seem to have been largely completed. Sinking of the Mississippi Embayment Syncline continued at least through the Eocene, and deep-seated seismic activity has continued to the present (McGinnis, 1963).

Time of mineralization

There is little evidence to place with any confidence the time of mineral deposition. Fluorite veinlets along fractures in the ultramafic dikes and in open spaces in the breccias indicate that mineralization occurred later than igneous activity. Some crushing of fluorspar has been noted along the faults, indicating minor fault movement since fluorspar deposition. However, fluorspar deposition occurred after major fault movement had ceased, probably some time in the Mesozoic. The faulting provides no evidence for assigning a minimum age.

From direct stratigraphic evidence, the ore deposits are post-Pennsylvanian in age and predate the Loveland Silt, which was deposited during the Illinoian Stage of glaciation (Baxter et al., 1963, p. 30). As most erosional levels of southern Illinois, including those that obviously truncate fluorspar deposits, are capped by the Mounds Gravel of Pliocene-Pleistocene age (Willman and Frye, 1970, p. 47-48), the mineralization is also pre-Mounds. From less direct evidence, it is reasonably certain that the deposits are considerably older than the erosion surfaces that intersect them. For example, fluid inclusion data suggest temperatures of fluorite deposition in excess of 100° C (Freas, 1961), but ore textures are not typical of surface or near-surface hot spring deposits. Therefore, it is probable that the deposits formed at moderate depths and earlier than the Mounds Gravel by the amount of time required to remove the rock above them, be it a few hundred or a few thousand feet.

In the final analysis, the only "certain" date is a maximum age of Permian, provided by the age of the pre-mineral ultramafic intrusions. A minimum age limit is provided by the erosion levels capped with the Pliocene or early Pleistocene Mounds Gravel, but it is fairly evident that the mineralization took place prior to deposition of the Mounds by a time interval necessary to remove several hundred feet of rock. The relation of deposits to faulting is of little help in determining age. It is apparent that mineralization postdates major displacement on the gravity faults, but the latter could have been accomplished any time from the end of the Paleozoic to early Late Cretaceous. In general, it would appear that mineralization took place probably sometime in the Mesozoic, but whether early, late, or somewhere in between is anybody's guess.

Stratigraphic and structural ore controls

The Illinois-Kentucky fluorspar district is located astride a broad domal anticline (Heyl et al., 1965, p. 9-12), the axis of which extends southeastward from the northwest corner of Hardin County, Illinois, into Kentucky. Hicks Dome, located on the axis near the northwest extent of the anticline, is a subsidiary structure probably formed by gaseous explosions subsequent to the broad arching of the anticline.

Hicks Dome lies between two major northeast-trending grabens, the Dixon Springs Graben on the west and the Rock Creek Graben on the east. Each is bounded on the northwest by a major fault or fault zone showing evidence of high-angle reverse movements. Along portions of their extents, the southeast sides of the major grabens are marked by a series of step-like faults that accumulate downthrow to the northwest.

The stratigraphic succession of the various formations exposed in the Illinois portion of the district (Baxter, Potter, and Doyle, 1963; Baxter and Desborough, 1965; Baxter, Desborough, and Shaw, 1967) is shown in figure 6. The Illinois area is largely underlain by rocks of Mississippian age; however, strata of the Devonian System crop out in the vicinity of Hicks Dome in northwestern Hardin County and formations of Pennsylvanian age occur on the flanks of the domal anticline and in the major grabens (fig. 2). Mineralization is largely confined to Mississippian strata, particularly the interval between the base of the St. Louis Limestone and the top of the Haney Limestone (figs. 6 and 7).

The rock-stratigraphic classification utilized in this discussion is the official classification followed by the Illinois State Geological Survey and differs in some respects from that used by U.S.G.S. mappers in the Kentucky portions of the district and by company geologists in both Illinois and Kentucky. These workers use the older terminology of Weller, Grogan, and Tippie (1952). Details of these differences are shown in figure 7.

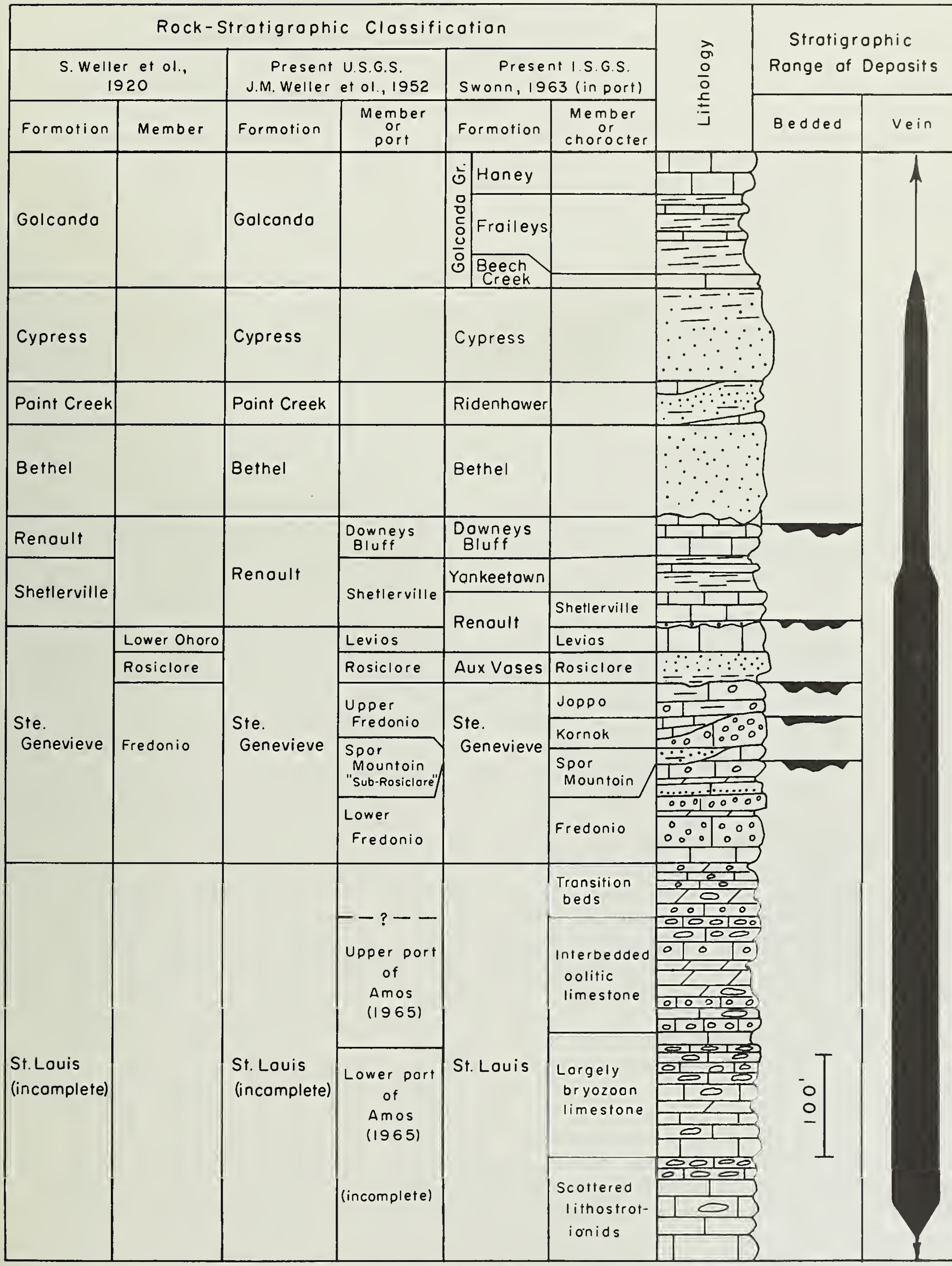

Fig. 7 - Lower Chesterian and upper Valmeyeran strata of the Illinois-Kentucky fluorspar district showing range of deposits. Terminology used by Saxby (Gaskins Mine, this guidebook) and Perry (Davis-Oxford Mine, this guidebook) is that of Weller, Grogan, and Tippie (1952).

Vein Deposits. The primary controlling factor determining the location and extent of mineralization of vein deposits was faulting. Major deposits have been found in northeast-trending faults of moderate displacement, 25 to 500 feet. These faults evidently provided avenues for the movement of mineralizing solutions and open fissures for mineral deposition. Faults of lesser displacement apparently failed to develop sufficient open space along fault planes, and those of greater displacement had excessive development of gouge and other fault material that decreased the amount of available open space.

The widest and most extensive vein deposits have been found where the fault walls are formed by competent Ste. Genevieve and St. Louis Limestones. In the Rosiclare district, the massive Bethel and Cypress Sandstones are also associated with more productive parts of veins. However, some commercial veins have been found in younger Chesterian strata, with little mineralization at deeper levels in older and presumably more favorable rocks.

Bedding-Replacement Deposits. The bedding-replacement deposits are located near and on the southeast side of a major northeast-trending structural element, the Rock Creek Graben. The deposits follow the course of a group of fractures and minor faults that trend N45° to N60°E and N30° to N85°W. The widest and most persistent ore bodies follow the northeast-southwest trends, parallel to the graben.

The restriction of bedded replacement deposits to certain stratigraphic levels (fig. 7) indicates that some beds were particularly favorable sites for replacement processes. The three major ore horizons are, in ascending order: (1) the level of the Spar Mountain Sandstone Member of the Ste. Genevieve Limestone, (2) the top of the Joppa Member of the Ste. Genevieve at the base of the Rosiclare Member of the Aux Vases Sandstone, and (3) the top of the Downeys Bluff Limestone at the base of the Bethel Sandstone. Less extensive replacement deposits have been found at the level of the Karnak Member of the Ste. Genevieve and at the top of the Levias Member of the Renault.

Grogan and Bradbury (1968, p. 395) list several possible common denominators among the three major mineralized horizons. All are limestone, the upper two are overlain by sandstone that is shaly at the base and could have acted as a dam to mineralizing solutions, and each favored interval may have been exposed to erosion or reworking during a depositional hiatus.

Solutional features that frequently accompany ore bodies may have exerted some local control over ore emplacement. Limestone strata frequently thin toward the center of the ore bodies, and the sandstone roof rocks dip inwardly toward the center. These have been interpreted either as "sag synclines" resulting from solution of the underlying limestone or as shallow-channel fillings (Grogan and Bradbury, 1968, p. 393-394). However, the minor presence of fluorite-cemented breccia at the top of ore bodies and the presence of collapse breccias within ore bodies attest to the solution of limestone host rock during deposition.

Brecke (1962, p. 511) describes two localized areas of intense solution activity and slumping in pipe-like structures as much as 250 feet in diameter. Such a structure in the North Green Mine showed Bethel Sandstone slumped 100 feet and the Rosiclare Sandstone 60 feet below their normal positions and mineralized breccia persisting below the replacement ore body to a depth of 110 feet below the Spar Mountain Sandstone. A similar structure occurs in Minerva No. 1 Mine. Although it cannot be demonstrated that these structures served as the main conduits for the ascension of mineralizing solutions from a deep-seated source, as suggested by Brecke, they represent sites of increased activity of such solutions.

Enroute, Site 4. Dixon Springs Graben

North of the Cache River Valley the route traverses the relatively rough terrain of the Shawnee Hills, an area underlain by alternating resistant sandstone and less resistant shales and limestones. The junction of routes 145 and 146 is located near the northwest boundary of the Dixon Springs Graben, one of two major northeast-trending grabens that transect the fluorspar district.

The Dixon Springs Graben extends from the northeast corner of Pope County southwestward to the Cache Valley, beyond which it is obscured by Embayment sediments. It is here bounded on the northwest by the Lusk Creek Fault Zone and on the southeast by a series of step-like faults that accumulate downthrow to the northwest (fig. 5).

The Lusk Creek Fault Zone is a complex structure and is a southwest-trending extension of, and is similar to, the Shawneetown Fault Zone. Evidence of high-angle reverse faulting is prominent. Minor mineralization along this zone marks the westernmost extent of the Illinois-Kentucky fluorspar district.

Enroute, Site 5. Hicks Dome

The apex of Hicks Dome is located approximately 3 miles east of Gaskins Mine (fig. 5). Limestone and chert of Middle and Lower Devonian age occur at or near the surface at the apex and occupy a topographic high completely surrounded by a belt underlain by shales of the New Albany Group and by an outer encircling ridge of chert, siltstone, and limestone of the Fort Payne Formation. Hicks Dome is an asymmetrical feature involving approximately 4000 feet of vertical uplift, with steeper dips on the north and northwest flanks and lesser dips in other directions. Hicks Dome is complexly faulted and is intruded by basic igneous dikes and breccias.

Enroute, Site 6. Rock Creek Graben

The Rock Creek Graben is the easternmost of the two major down-dropped blocks that transect the Illinois fluorspar district. In eastern Hardin County, the graben trends approximately N55°E and is bounded on the northwest by the Hogthief Creek and Goose Creek Faults and on the southeast by the Peters Creek Fault or by step-fault branches of the Peters Creek Fault. North of Rosiclare, this trend changes somewhat abruptly, with the bounding faults and enclosed graben striking approximately N20°E.

The field trip route intersects the graben at this change in direction, and at this point the northwest side of the structure is marked by a complex fault system that, at places along its extent, shows evidence of high-angle reverse movement. The graben here is $1\frac{1}{2}$ to 2 miles wide, and the southeast side is marked by a series of faults, some of which are mineralized and are northward extensions of the Rosiclare district vein deposits.

STOP 1

GASKINS MINE

D.B. Saxby
Chief Geologist, The Minerva Company

Minerva Oil Company's Gaskins fluorspar mine is located in the NW¼, sec. 34, T. 11 S., R. 7 E., Pope County, about 10 miles northwest of Rosiclare, Illinois.

The ore, fluorspar with some galena and sphalerite, occurs as vein-filling averaging 5 feet wide and as bedded replacement ore up to 35 feet wide along a double fault system (fig. 8). Ore occurs opposite Mississippian formations, mostly limestones, from the base of the Bethel Sandstone for about 250 feet downward (fig. 9). In the north vein better ore widths were encountered in the upper levels, but in the south vein the better widths occurred in the lower levels.

Vertical displacement along the fault system ranges from 25 feet to 70 feet, but the fault movement was mainly horizontal, with the north side moving west relative to the south side. The beds and ore zone dip about 10^{o} to the west, as indicated in figure 9. Another vein system of similar strike is being developed about 500 feet to the north.

The ore is mined by small rubber-tired end loaders and trucks. Shrinkage stoping was employed in the upper part of the mine, but modified sub-level mining is being used in the lower part of the mine, following the ore zone down an incline to the west and onto the adjoining Stacy property.

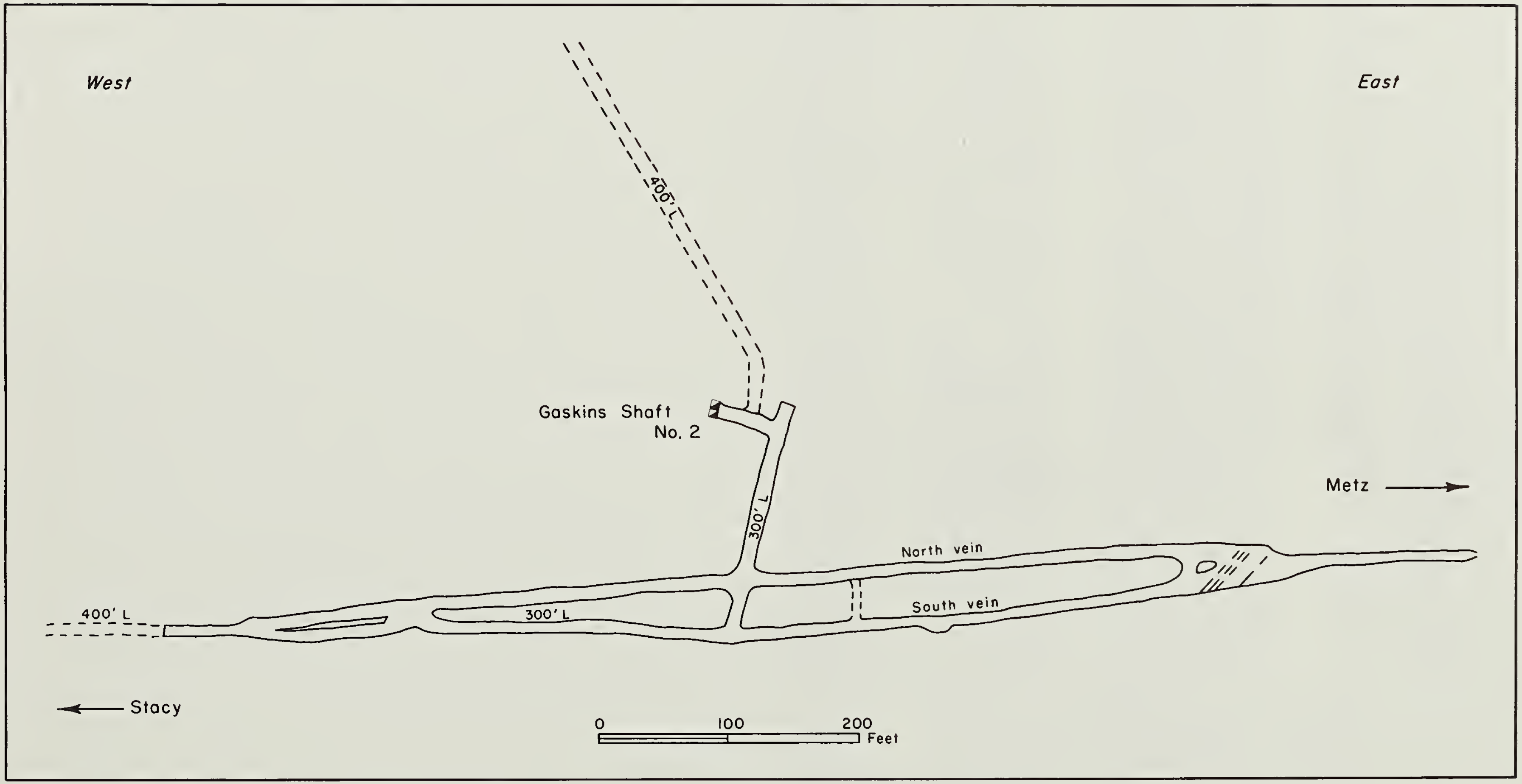

Fig. 8 - Plan view of Gaskins Mine.

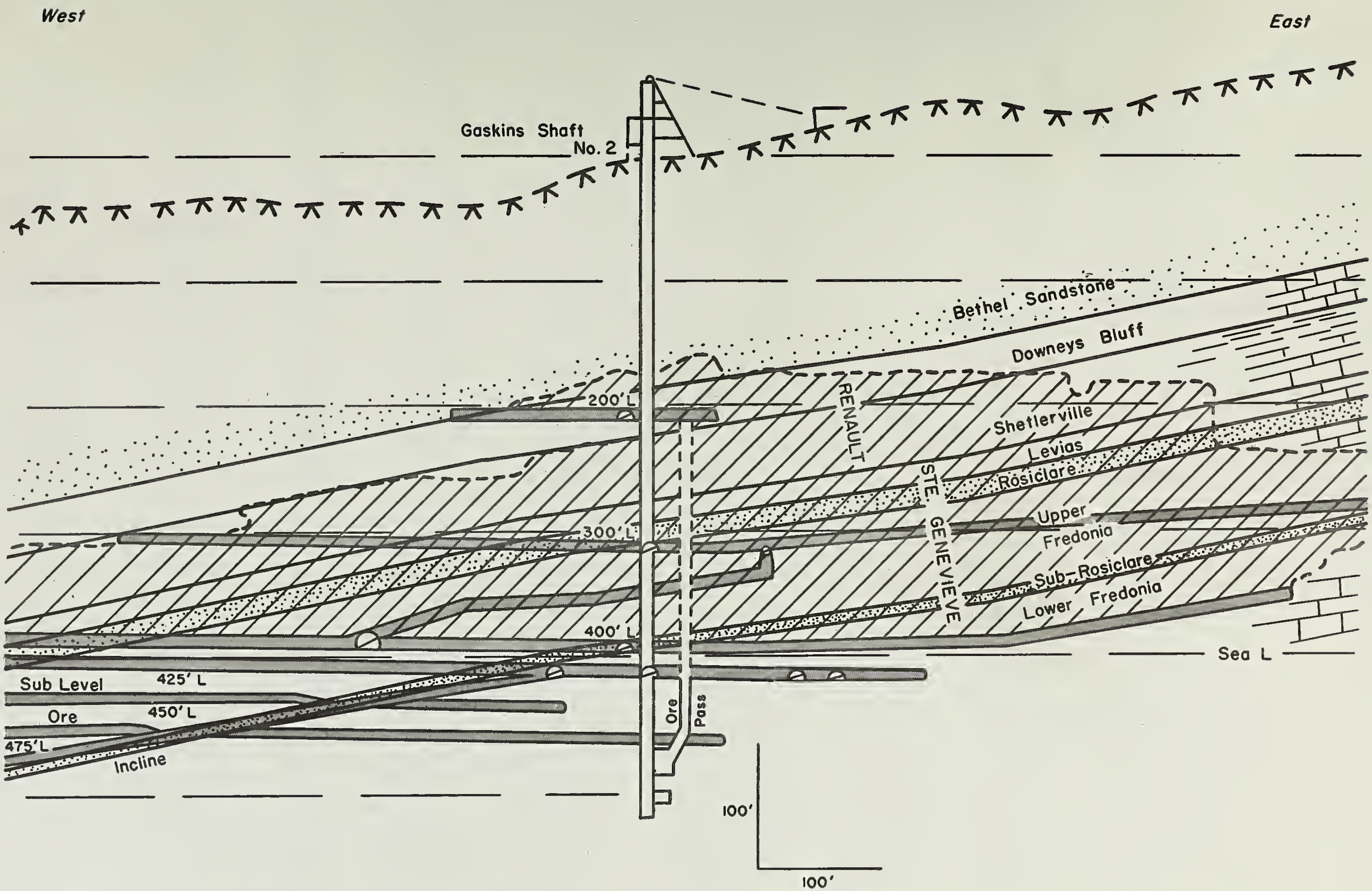

Fig. 9 - Longitudinal projection, Gaskins Mine. Extent of stoping on the two parallel veins shown by diagonal pattern. Stratigraphic nomenclature is that of Weller, Grogan, and Tippie, 1952 (see fig. 7).

STOP 2 THE DAVIS-OXFORD ORE BODY

B. L. Perry
Chief Geologist
Ozark-Mahoning Company, Mining Division

The Davis-Oxford ore body is a typical stratiform, replacement-type fluorspar deposit, located in the Cave in Rock, Illinois, mining district. This ore body constitutes the southern half of a continuously mineralized zone approximately 14,000 feet in total length. The average width of the ore body is 150 feet and the height is in excess of ten feet.

The north end of the Davis-Oxford ore body is currently being mined through the Ozark-Mahoning Company's No. 7 shaft and the south portion of the ore body is mined through its heavy-media plant shaft (fig. 10). Trackless equipment is utilized in mining by room and pillar methods.

Geologically, the Davis-Oxford ore body consists of an elongated northeast-southwest striking replacement body lying immediately beneath the Mississippian Bethel Sandstone. The ore body dips gently to the northeast, conformable to the local dip of the stratigraphy.

The major portion of the ore consists of a fluorite replacement of upper portions of the Renault Limestone.* In a few instances, however, it is apparent that some of the fluorite occurs as void-fillings rather than as replacement ore. A few very calcareous zones within the lower part of the Bethel Sandstone are replaced; however, no replacement of silica has been observed.

The fluorite in this ore body occurs as yellow high-grade zones and associated purple, lower grade material. The purple ores appear to have been formed by the replacement of calcareous material; however, the yellow fluorite appears to have been formed by both void-filling and replacement processes.

Sphalerite and barite are the other important mineral constituents of this particular ore body. Sphalerite is generally concentrated in or near minor faults within the mineralized zone, and barite is concentrated along the periphery of the ore body.

Visible galena is extremely rare; however, scattered pyrite and marcasite are common. Chalcopyrite and witherite have been observed in trace amounts.

Structurally, the ore body appears to be associated with a northeast-southwest striking zone of irregular and discontinuous faults and fractures. An accompanying sag in the overlying Bethel Sandstone is normally an associated structural feature (fig. 11).

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*Downeys Bluff Limestone of current Illinois State Geological Survey classification (see fig. 7).

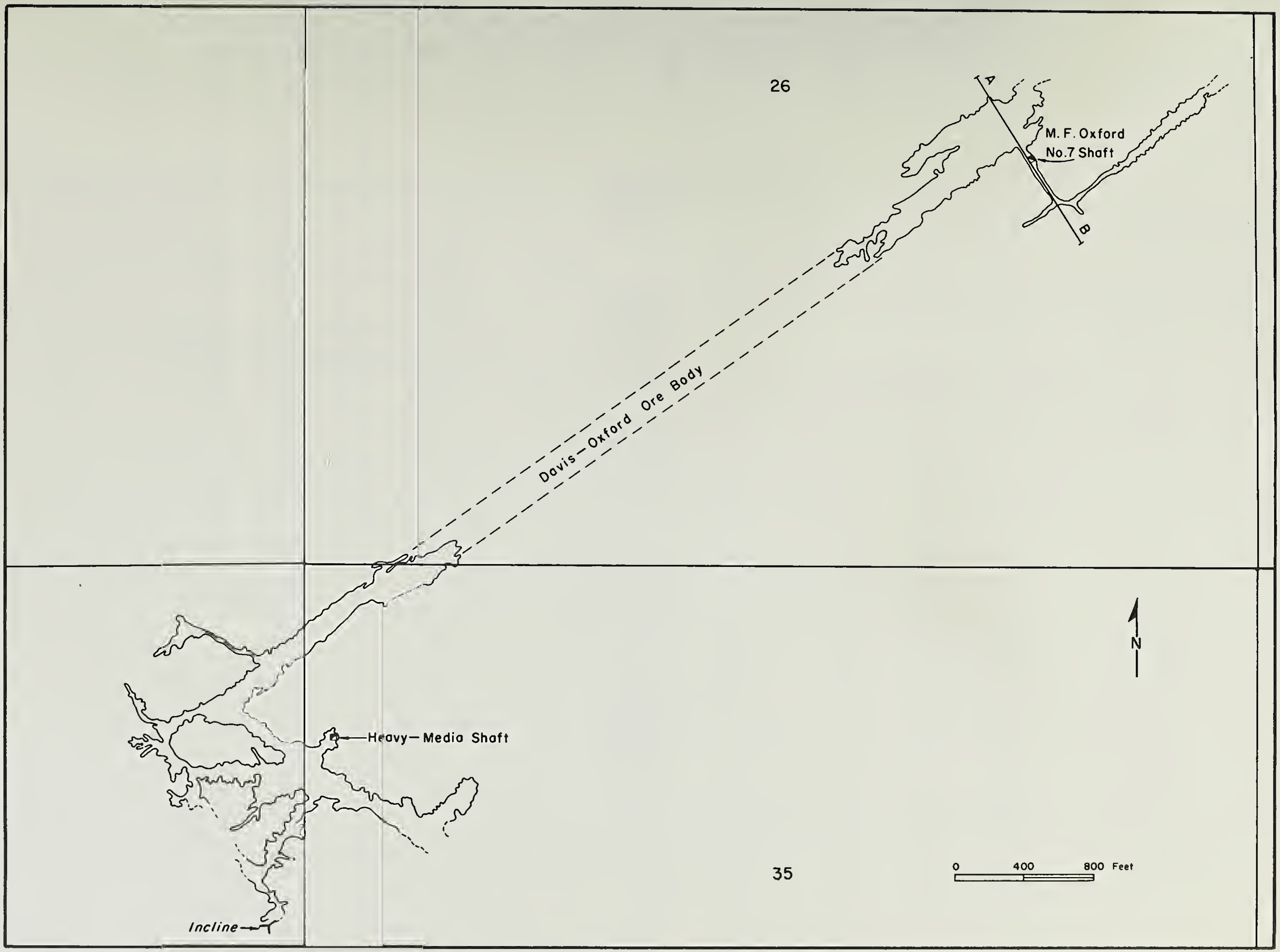

Fig. 10 - Plan view of workings, Davis-Oxford ore body, and location of cross section A-B.

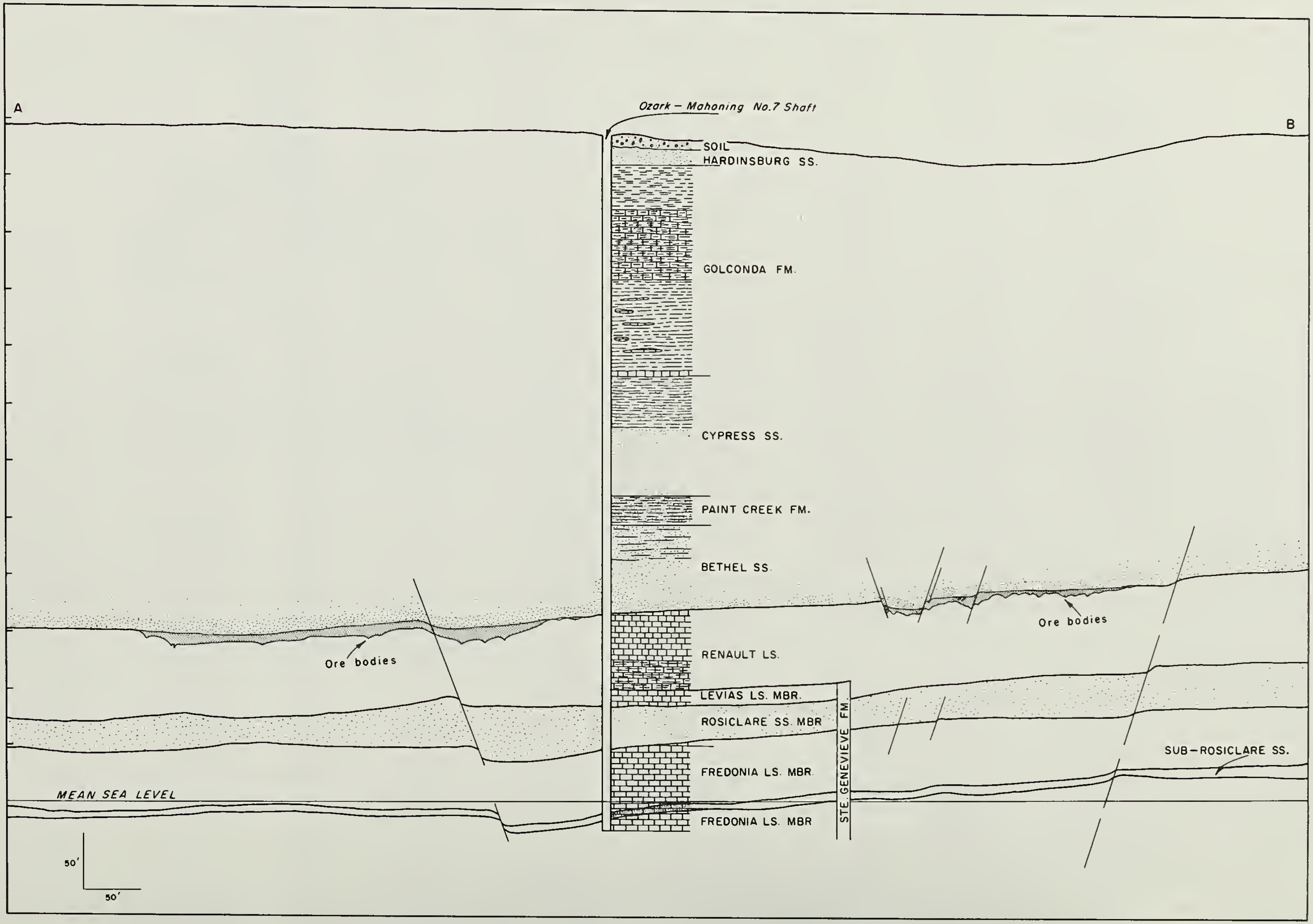

Fig. 11 - Cross section A-B through M. F. Oxford No. 7 shaft, looking northeast. Stratigraphic nomenclature is that of Weller, Grogan, and Tippie, 1952 (see fig. 7).

The top portion of the ore usually lies directly against the base of the Bethel Sandstone, but the bottom of the ore is irregular, as indicated by the cross-section sketch (fig. 11).

Ore bodies that occur at other stratigraphic horizons exhibit somewhat different traits; however, it is felt that the Davis-Oxford ore body represents a typical Bethel-horizon replacement-type occurrence.

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